ARI Special Report 59

Virtual Environments for Infantry Soldiers

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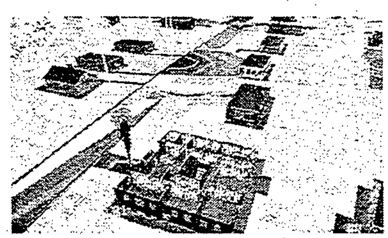

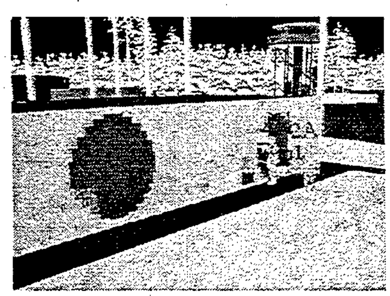

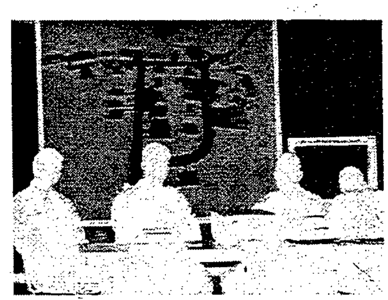

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U.S. Army Research Institute
for the Behavioral and Social Sciences

Virtual Environments for Infantry Soldiers

Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal

ARI Special Report 59
May 2004

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FOREWORD

The U.S. Army needs a capability to effectively incorporate the performance of Soldiers in virtual simulations. In current fielded systems, such as the Close Combat Tactical Trainer, dismounted combatants are involved in the combined arms operation in an artificial and generally unsatisfactory manner. Virtual simulation can provide a means for infantry leaders, Soldiers and units to train effectively over a wide range of conditions. The same technologies can also be used for development of new Infantry concepts and doctrine and applied to development of mission planning and rehearsal tools. The capability to use effective virtual simulations for all combatants has implications for training of today's leaders and Soldiers and for the development of effective Future Force concepts and systems.

Emerging Virtual Environment (VE) technologies, such as low cost computer image generators, locomotion platforms, intelligent computer-controlled forces, and immersive displays, have the potential to provide training, mission rehearsal, and experimentation capabilities for individual Soldiers and leaders. However, the potential of VE is currently unrealized because critical hardware and software, documented effective training methods and strategies, and training support tools need to be developed and integrated.

In response to this need, the U.S. Army Research Institute Simulator Systems (ARI-SSRU) and Infantry Forces Research Units (ARI-IFRU), the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), and the U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) and Computational and Information Sciences Directorate (ARL-CISD) participated in a joint Science and Technology Objective (STO) entitled "Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal." STOs are fundamental building blocks of the Army's process to "deliver" technology within a scheduled timeframe based on need. Only the 200 highest priority efforts in the Army's advanced technology development and applied research programs can be designated STOs. This four-year effort (fiscal years 1999 through 2002) was focused on overcoming critical technological challenges that prevented effective individual Soldier simulation. This report provides a relatively brief, non-technical description of the accomplishments of that STO.

Zita M. Simutis

ZITA M. SIMUTIS
Director and Chief Psychologist
of the United States Army

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Introduction

After the smoke cleared and the shooting died down...SGT Asoma slumped in his chair – tired and drained, but in a good way. It had been a tough mission, and they had been successful in rescuing all of the hostages with no injuries. Even the guerrillas were taken alive.

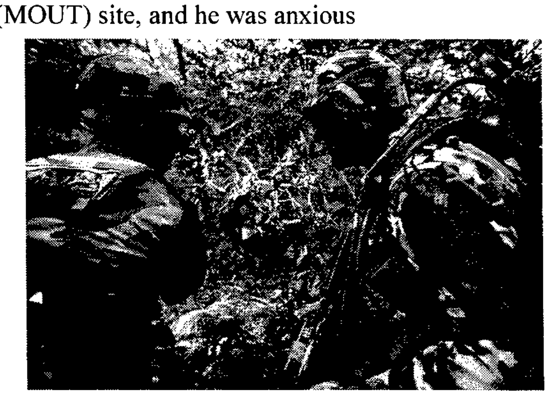
It felt especially good after the fiasco they had made on their first attempt. He could still feel that sick sensation when half the squad was killed, half the platoon if you count the other squad, too. He looked around the area – he could tell that the rest of his squad was feeling good now too.

They'd had some very tough missions – crowd dispersal, counter-sniper operations, clearing a building. Trying to rescue people in a downed copter with somebody taking shots at you across the square. Daylight, darkness, fog – a little of everything.

As the after action review (AAR) started, he thought about the exercise and how real it felt. You know you're in a simulation, but you still get pumped when you succeed and feel rotten when you screw up, even when you know that you're not really seeing your buddies dead. You're not really running through the smoke, hoping it was laid on right for the wind, or peering around buildings, or climbing through holes in walls, but you might as well be for the adrenaline rush you feel.

The AAR would help to consolidate the improvement they'd made. The AAR playback capability would let them see what really happened, so they could verify their procedures and understand better how to assess the situation and deal with it. They could even see through the building's walls and onto every floor and see what the guerillas were seeing. With the AAR features, they were able to work on their standing operating procedure (SOP) and tighten up their movements. He could sense that they were becoming a team, learning how to move, how to cover themselves – and each other. And he was learning how to position them, monitor the situation, and respond to the unexpected.

Next week they would be at the urban operations (MOUT) site, and he was anxious to see how their new skills would hold up in a live simulation exercise. Then back to virtual simulation to practice more missions, using the terrain database of their deployment area. And just a few weeks later, on their way to the real thing, halfway around the world.



Training was not the real thing, no doubt about it. But SGT Asoma was feeling a lot more confident about how they'd do in-country after getting these chances to hone their skills in simulation.

Virtual Environments for Infantry Soldiers

ADVANTAGE:
Virtual Environment

- *Safety*
- *Cost-Effectiveness*
- *Less Wear and Tear on Environment*
- *Controlled and Varied Scenarios*
- *Instrumented Measurement*

Simulation-supported training has become a way of life for Army mounted maneuver forces, but it has been little more than a novelty for the dismounted Soldier. Using realistic scenarios and virtual simulation systems, such as the Close Combat Tactical Trainer (CCTT), armor and mechanized infantry units from platoon through battalion levels are able to acquire and refine skills, refresh their skills after long deployments, prepare for major live exercises, and rehearse actual missions on accurate terrain representations against aggressive and skilled opposing forces (OPFOR). By using simulation, they save time and money, inflict less damage on the environment, run a lower risk of injuries, and are able to portray precise variations in conditions, deliberately designed to stress particular abilities and activities.

Individual Soldiers have no simulation systems that allow them the same advantages. The interaction of a group of individuals with a computer-generated environment presents enormous technological challenges if any degree of realism is to be achieved. A Soldier on foot is in immediate contact with the sights, sounds, touches, and smells of the "real world," rather than being in the easily-simulated environment of a vehicle compartment. Having a virtual environment (VE) that allows Soldiers to interact with that "real world" – in simulation – would provide them with all the training and other capabilities available to Soldiers in tanks and other vehicles:

- Opportunities for conducting realistic collective training more safely and cost-effectively.
- Training exercises that are standardized, repeatable, and varied.
- Instrumented tools to measure and analyze performance and provide better feedback.
- Environments for staging realistic mission rehearsals.
- The ability to conduct concept exploration, to try out fighting and organizational techniques in a controlled and instrumented environment.
- The ability to test equipment and system concepts in controlled and varied circumstances with reliable measurement techniques.

STO Intent: *A training system for individual Soldiers that is realistic and effective, yet requires a fairly low level of personnel support for subordinates and role players.*

Now, technological breakthroughs and the results of human-in-the-loop experiments are bringing the vision of VE for individual Soldiers closer to reality. This report describes the work on a Science and Technology

Objective (STO) entitled *Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal.* STOs are fundamental building blocks of the Army's process to "deliver" technology within a scheduled timeframe based on need. Only the 200 highest priority efforts in the Army's advanced technology development and applied research programs can be designated STOs. The STO activities and goals were focused on overcoming critical technological challenges that prevented effective Infantry Soldier simulation. It has been an ambitious and scientifically broad program of research, with the U. S. Army Research Institute for the Behavioral and Social Sciences (ARI) leading a team of both government and industry developers in examining simulation capabilities for Infantry Soldiers. The other government partners were the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM[1]) and the U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) and Computational and Information Sciences Directorate (ARL-CISD).

Early Research on Virtual Environments for Infantry Soldiers

General (Ret.) Paul F. Gorman is regarded as the moving force for initiating research on the use of VE for dismounted combatant training. His 1990 paper describing the concept of an individual portal, or I-Port, as the interface between Soldiers and virtual environments led to work by ARI and other agencies investigating the feasibility of using VE technology for Soldier training. Figure 1 shows a broad timeline of the progress in the VE research that occurred prior to the beginning of the STO.

Following initial development work, STRICOM initiated the Dismounted Warrior Network (DWN) and DWN Enhancements for Restricted Terrain (DWN ERT) programs. DWN

Events leading up to the Virtual Environments (VE) Science and Technology Objective (STO) laid the groundwork for the research objectives...

Year	Events and Activities	Further described in...
1990	General Gorman calls for the development of an individual portal into virtual worlds.	Gorman, P.F. (1990). *Super troop via I-Port: Distributed simulation technology for combat development and training development.*
1990	Conference in Snowbird, Utah in fall 1990 to discuss individual Soldier systems and the role that an individual portal would play in their development.	Goldberg, S.L., & Knerr, B.W. (1997). *Collective training in virtual environments: Exploring performance requirements for dismounted soldier simulation.*
1991	U.S. Army Research Institute (ARI) research and development (R&D) program initiated as conference outcome, to examine the use of virtual environment (VE) technology for Infantry Soldier training and to identify technical problems and research issues.	Levison, W. H., & Pew, R. W. (1993). *Use of virtual environment training technology for individual combat simulation.*
1992	ARI research provides a detailed delineation of infantry unit tasks and expected VE capabilities.	Jacobs, R. S. et al. (1994). *Behavioral requirements for training and rehearsal in virtual environments.*
1994-1996	Experiments investigate how well a fire team in a dismounted infantry semi-automated forces (DISAF) training environment can support military operations in urban terrain (MOUT) tasks at the individual soldier, fire team, squad, and platoon levels.	Lockheed Martin Corporation. (1998). *Dismounted warrior network enhancements for restricted terrain final report.* Salter, M. S., Eakin, D. E., & Knerr, B. W. (1999). *Dismounted warrior network enhanced restricted terrain (DWN ERT): An independent assessment.*
1995-1996	Omni-Directional Treadmill (ODT), developed to support locomotion by soldiers in simulation, is worked into the VE suite; utility is limited by engineering challenges and excessive noise at high speeds.	Darken, R.P., Cockayne, W.R., & Carmein, D. (1997). *The Omni-directional treadmill: A locomotion device for virtual worlds.*
1996-1998	Research in dynamic terrain initiated, centering on protocols for representing wall breaching, dings, rubble and debris, and physics-based wall damage.	Thomas, M. A. (1998). *The ARL Experiment 3 individual combatant/military operations on urbanized terrain (MOUT) demonstration.* Neiderer, A., Thomas, M.A., & Pearson, R. (1998). *A fracturing of polygonal objects.*
1996-1998	ARI reports on the use of the various VE technologies and capabilities to train individual soldiers and describes the vision for additional research.	Knerr, B. W., Lampton, D. R., Singer, M. J., Witmer, B. G., Goldberg, S. L., Parsons, K. A., & Parsons, J. (1998). *Virtual environments for dismounted soldier training and performance: Results, recommendations, and issues.*

Figure 1. Research activities leading up to the Virtual Environments (VE) Science and Technology Objective (STO).

[1]The portion of STRICOM performing the work is now the Research, Development, and Experimentation Command Stimulation Technology Center (RDECOM STC).

investigated the capabilities of reliable, low-cost, easy-to-use systems to insert Infantry Soldiers into VE. A series of experiments was conducted during 1997 and 1998 to explore the utility of such systems as research and analysis tools, and to investigate different interfaces for inserting Soldiers into virtual simulations. Each year, a set of individual combatant simulators was selected based on three criteria: a desire to have a diverse mixture of characteristics to examine; a cost/benefit assessment of system characteristics; and expected system availability. The various simulators, with supporting hardware and software, were tied into a distributed interactive simulation (DIS) network and installed at the Dismounted BattleSpace BattleLab Land Warrior Testbed (LWTB)[2] in Fort Benning, Georgia.

The initial set of experiments showed that the DWN could be used to assess the utility of the emerging immersive simulation technologies (Lockheed Martin, 1997) both from a part-task engineering perspective and from a mission-oriented user perspective. ARI-Simulator Systems Research Unit (SSRU) and ARI-Infantry Forces Research Unit (IFRU) participated in the design and conduct of the experiments (described in Pleban, Dyer, Salter, & Brown, 1998). The goal of the second set of experiments was to investigate how well a fire team of virtual individual combatant simulators and dismounted infantry semi-automated forces (DISAF) could support MOUT tasks at the individual Soldier, fire team, squad, and platoon levels. Engineering experiments, live tests at the McKenna MOUT site, and user experiments were conducted. The results, which are documented in Lockheed Martin Corporation (1998) and Salter, Eakin, and Knerr (1999), indicated that the technologies showed sufficient promise that a concentrated research and development effort was justified.

Future operational capabilities described in TRADOC Pam 525-66 (TRADOC, 1997):

- Highly realistic training available through means other than on-the-job or field training, including training for dismounted Soldiers and small group leader training.
- Training and mission rehearsal on tasks that require multiple repetitions to achieve proficiency when repetitions would not otherwise be possible.
- Dual capability of being an effective training tool as well as providing the ability to evaluate warfighting concepts and battle planning.
- Realistically simulated friendly and opposing forces necessary to train and rehearse tasks realistically within advanced simulation.
- Capability to develop and deliver training and mission rehearsals, on demand, to meet contingency mission requirements.

By 1998, after conducting a number of VE man-in-the-loop experiments, researchers at ARI-SSRU in Orlando, Florida had reached the point where it was possible to synthesize what they and other researchers had found, draw initial conclusions, and make recommendations for the use of VE for U.S. Army training. Their research had explored the types of tasks for which VE training was most appropriate; the characteristics of VE systems that were required to provide effective training; and the training strategies that were most effective in VE.

The early research and development activities offered promise that VE technologies, such as low cost computer image generators, locomotion platforms, intelligent computer-controlled forces, and immersive displays, could have the potential to provide training, mission rehearsal, and experimentation capabilities for Infantry Soldiers and leaders. Yet the potential of VE was still unrealized because critical hardware and software gaps were not fully defined, effective training methods and strategies had not been explored and

[2] Now the Soldier Battle Lab Virtual Simulation Lab.

documented, and training support tools needed to be developed and integrated. A seminal report on the findings (Knerr et al., 1998) delineated what was known and where the research should proceed in order to achieve the potential for individual Soldier training in VE.

Science and Technology Objective: Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal

A four-year (Fiscal Year [FY] 99-FY 02) STO effort was proposed to address a range of U.S. Army future operational capabilities described in U.S. Army Training and Doctrine Command (TRADOC) Pamphlet 525-66 (U.S. Army Training and Doctrine Command, 1997). The overall goal for the STO was ambitious: To develop a demonstration leader trainer at the fire team, squad, and platoon level. The envisioned system would include a variety of features:

- Leader trainees would be able to execute a series of realistic training scenarios (combat operations and support operations) in the simulator.
- Subordinates, other friendly forces, enemy forces, and civilians would be represented by computer-controlled or semi-automated agents.
- Repeated practice, enhanced by training features, coaching, and AARs, would build decision-making and coordination skills.

Five government organizations that had previously initiated research and development programs related to the use of VE for individual Soldier simulation came together to collaborate on the research and development. Each of the major players (shown in Figure 2) had a particular area of interest, but all worked together to explore

STO Participants	Focus Area
U.S. Army Research Institute (ARI) Simulator Systems Research Unit (ARI-SSRU), Orlando ***ARI Infantry Forces Research Unit (ARI-IFRU), Fort Benning***	• Tasks suited for virtual environment (VE) training • Capabilities of VE technologies • Effectiveness of VE-based training • Team and distributed teams training approaches • Performance measurement and feedback • Side effects of VE
U.S. Army Simulation Training and Instrumentation Command (STRICOM)	• Performance and interoperability of devices and technologies • Development of interfaces for participants and trainers • Visual display system simulating night vision sensors and equipment. • "Intelligent" computer-controlled forces to represent enemy, friendly, and neutral forces • Voice control of computer-controlled forces • Representation of various weapons and devices
U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate (ARL-HRED)	• Locomotion simulators and devices that provide realistic perception of movement and accurate energy expenditure
ARL Computational and Information Sciences Directorate (ARL-CISD)	• Dynamic terrain, including damage to structures, rubble and other micro-terrain obstacles

Figure 2. STO participating agencies and areas of interest.

concepts and systems and to recommend directions for further work on training, concept development, and mission rehearsal.

Picture This: What is the Individual Soldier's Virtual Environment?

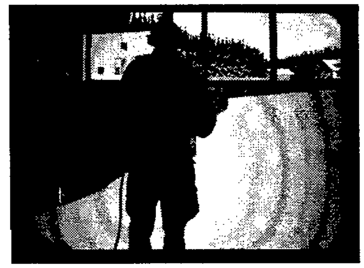
Unless you have seen a virtual simulation for Infantry operations, it is difficult to appreciate the hurdles that had to be overcome and to gain a vision of the environment for training. This short section provides a "guided tour" of one such environment, based on a recent experiment in the Soldier Battle Lab at Fort Benning.

First, understand what the virtual environment needs to convey:

- Realistic representation of terrain in different conditions (e.g., night, fog) – *How will the Soldier see his environment?*
- Locomotion devices that provide realistic perception of movement and some degree of accurate energy expenditure – *How can he move or change position? How can he cross a field or climb stairs?*
- Ability to select weapons and other systems and use them with realistic effects – *How will the Soldiers be able to use his M4 rifle, throw smoke grenades or concussion grenades, and use binoculars or night vision devices?*
- "Intelligent" computer-controlled forces to represent enemy, friendly, and neutral forces – *How can the simulated people react to the Soldier's actions? Will they fall when shot, and walk around rather than walk into Soldiers and other obstacles?*
- Dynamic terrain showing damage to structures, rubble and other micro-terrain obstacles – *How can scenery features (such as trees, cars, and street lights) also "behave" like their real world counterparts? Will buildings and other structures show effects of the Soldier's actions?*
- Accurate portrayal of Soldier actions and movements in the virtual environment *–How do the Soldiers see each other or interact?*
- Voice and gesture recognition by DISAF "Soldiers" – *How can leader trainees control computer-generated Soldiers with voice and hand-arm signals?*
- Performance recording, analysis, and tailorable feedback at AAR station – *How can a trainer know what's going on in the simulation, so there can be appropriate feedback and performance improvement?*

The squad is organized as it would be in the "real world": a squad leader and two four-man fire teams. In the real world, the squad leader gives them their mission, and off they go, between buildings and behind trees, carrying rifles, smoke grenades, and concussion grenades. They may not have visual contact during much of the mission

but may communicate by radio. When they are in visual contact they may communicate by hand and arm signals, or by voice. They move stealthily or rapidly or under cover of smoke, they hide, they peer around corners. They shoot and get shot at, and sometimes they get hit.



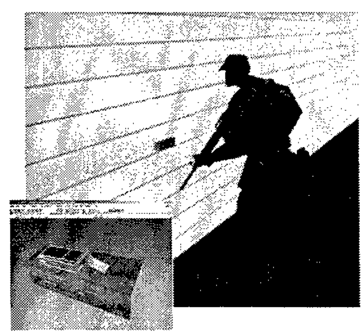
In the virtual environment, each Soldier is in a separate ten-foot square cubicle with the computer-generated scenery projected on the wall in front of him; the other three walls function to separate him from the "outside world."

In the virtual environment, the buildings, trees, enemies, smoke, and fires are simulated. They have a realistic appearance, and in critical aspects are as reactive to what the Soldiers do as real environmental features would be. In fact, they are computer-generated images, projected onto a screen. Each Soldier is in a separate ten-foot square cubicle with the computer-generated scenery projected on the wall in front of him; the other three walls function to separate him from the "outside world." An acoustic tracking system is used to identify the position and posture of the immersed Soldier. The tracking system recognizes sensors located on the Soldier's weapon and head. To make his view change as he walks closer or changes position or moves his head, the sensors communicate to the computer the specifics of his position, and the scenery changes to match.

Soldiers in the virtual environment carry a modified M4 rifle that also holds the controls for other weaponry and devices. The Soldier is wired with sensors that communicate his position and posture to the simulation system, which then portrays the Soldier realistically in the virtual environment.

There is a switch on each Soldier's M4 rifle that works like a joystick, by which he indicates that he is walking, running, or turning. Although he may not be actually moving toward a wall, the wall will appear to be getting closer as the computer interprets his position and speed. Another switch on his weapon gives him the capability to employ grenades, explosives, or other devices.

Shooting enemy Soldiers occurs as it would in the real world. As a Soldier aims his weapon and fires, the computer senses the Soldier's aim, the position of people in the affected area, and the capability of the selected weapon system, and from that information determines a hit, a kill, or a miss. If it's a kill, the victim (virtual or DISAF) is out of action – appears to fall down and no longer has any activity. Non-lethal hits result in reduced capabilities for the victim, such as reduced movement rates or inability to use their weapon.



Soldiers are furnished with virtual weapons such as grenades and satchel charges that can be employed by means of switches on the Soldier's M4 rifle. This satchel charge can be emplaced on a structure to blow a hole in the wall.

Buildings are reactive as well. For example, if plastic explosive is detonated on the wall of a building, the Soldiers sees a hole in the building, smoke and dust, and rubble on the ground. The Soldiers can move through the simulated breach in the simulated wall to gain entry to the building.

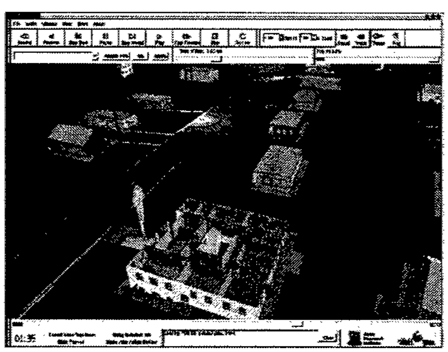
Sensors provide information that is translated into a virtual representation of the Soldier so that each trainee is able to see where his buddies are located and what they are doing.

The same sensors that allow the computer to generate the Soldier's view and position also provide a moving image, or avatar, of the Soldier – his posture, orientation, and movement speed. The information is translated into a virtual image of the Soldier, and the image is projected onto the walls of the other Soldiers' cubicles along with the other scenery. The images are oriented correctly and scaled appropriately to represent how the Soldiers should appear to each other. Their voice communications are conveyed by means of microphones and earphones.

The virtual simulation environment includes computer-generated Soldiers or civilians who will move and react in response to gestures and voice commands of the real Soldiers.

The simulation environment includes DISAF: totally computer-generated Soldiers or civilians. DISAF Soldiers can fill in squads or fire teams when only the leader is present for training. They can also represent adjacent friendly units or enemy Soldiers. When a leader's squad members are DISAF he is able to give them commands using voice recognition technology, just as he does to live Soldiers, and the computer-generated forces react appropriately.

A data collection system records all of the activity, and the information can be re-assembled in the form of a recording that can be viewed from any angle and in any sequence of events. The system even portrays a "top-down" presentation of movements though buildings with the ceilings removed to permit viewing during playback. Another special tool shows participants a "snail trail" of where they went and what rooms or areas were not searched or cleared. Synchronized with voice recordings, the playback provides a ground-truth representation of what happened during the mission.



The After Action Review (AAR) system allows trainers to observe the exercise from any angle or distance, and can show buildings with ceilings removed and with a "snail trail" showing where Soldiers moved during the exercise.

These effects and capabilities are the subject of the technology experimentation listed in Figure 2, and were at the heart of the STO efforts. For the four years of the program, researchers worked to improve and bring together all of the technologies, ensure seamless translation of data among the technologies, and explore the training and mission rehearsal value of the simulation.

The STO in Action

During each year of the STO there have been three major types of activities: research and technology development, conduct of experiments examining training approaches and training effectiveness, and preparation for and conduct of a culminating event (CE). The CEs were comprehensive demonstrations and assessments conducted with military personnel, using as much of the developed technology as was feasible in a realistic training exercise. Each CE gave researchers the chance to integrate and evaluate the technologies developed during the year. The goal was to insure the compatibility of the technologies and to obtain feedback from Soldiers on the utility of the technologies for training purposes.

The emphases during the first year of the STO (FY 1999) were on identifying high-payoff small unit leader training applications and beginning concentrated efforts to improve computer-generated forces capabilities. The second year of the STO (1999-2000) continued with a focus on the lessons learned during the first year, particularly those from the first CE. The DISAF was further developed to improve and expand their behaviors. Several alternative mobility interfaces that represented Soldier movement through the simulated terrain were assessed, and development of night vision simulation received special attention.

Specific training research issues were also being investigated by ARI during this time. The areas of interest included such diverse human aspects as the effectiveness of different methods of providing feedback, training and assessment of decision-making skills, team performance and team instructional strategies, and measures of situational awareness, all within the context of VE for Infantry Soldiers. By using the VE as a testbed in conducting parallel lines of research on technology and human performance and training, ARI and its STO partners intended to ensure that the resulting findings addressed more than interoperability and futuristic features, providing also the data that would support construction of effective tools for training.

By the third year of the STO (2000-2001), the focus was broadened to include a heavy emphasis on the human interface aspects of the VE systems for training, including the use of automatic speech recognition to control DISAF, development of an AAR system, evaluation of night vision simulation techniques, and incorporation of a broad range of DISAF behaviors. At the same time, the technologies were becoming more mature and stable, and interoperability issues were being addressed with increasing success. Training continued to be a principal area of investigation.

In the final year of the STO (FY 2002), there was a concerted effort to meet the STO's objectives for technology integration, to document the training potential of the systems, and to prepare recommendations for the road ahead. Following a year of research on mission rehearsal and training transfer, the FY 02 CE was held in August 2002 at the Soldier Battle Lab.

The following section describes the conduct of the CEs. Because all of the prior experimentation and technology development came together in the final CE, its conduct and findings and outcomes are discussed in some detail.

Conduct of the Culminating Events

Each CE was a combination of equipment integration with intensive system testing, scenario-based structured exercises with infantry Soldiers as training participants, after action reviews of each exercise to provide performance feedback, and post-exercise data collection from all military and support participants. Every CE was a collaborative effort involving, in addition to the military personnel and government organizations already identified, representatives of the various contractors who were involved in technology development and testing.

The configuration for the final CE, shown in Figure 3, demonstrates both the requirements for interoperability and the complexity of those requirements. The configuration included six individual immersive Soldier simulators, used by the squad leader, the two fire team leaders, and the three members of one of the fire teams. The simulators were identical, except for additional equipment for the leader of the other fire team – a voice recognition system to enable communication with the virtual team members. All of the individual simulators were equipped with ASTi™ radio headsets, which permitted verbal communication on up to two channels, depending on the duty position. The squad leader could talk to his fire team leaders and the platoon leader (a role player). Each fire team leader could talk to the squad leader and his subordinates. Fire team members could talk among themselves and with their fire team leader.

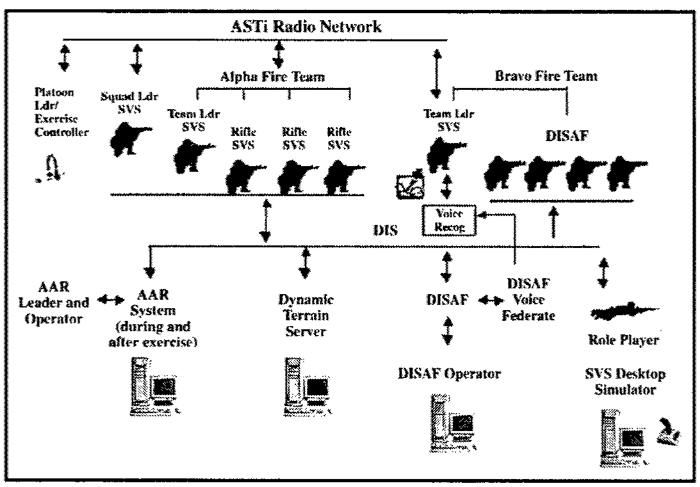


Figure 3. The configuration for the final culminating event exercises included six Soldier Visualization Systems (SVS) individual immersive Soldier simulators, used by the squad leader, the two fire team leaders, and the three members of one of those fire teams. Behind the scenes, there were the Voice Recognition system; two Dismounted Infantry Virtual After Action Review Systems (DIVAARS); the dynamic terrain server; one BattleMaster operator station for use by the Dismounted Infantry Semi-Automated Forces (DISAF) operator and the exercise controller; and a desktop SVS used by a role player to represent various virtual participants, including the platoon leader and an enemy combatant.

Elements of the system that were "behind the scenes" included the Voice Recognition personal computer (PC); two AAR systems, each comprising two PCs; the dynamic terrain server; one simulator control operator station for use by the exercise controller and a DISAF operator; and a desktop simulator used by a role player to represent an enemy combatant.

Associated Press

Dlubac, El Polksa

The U.N. Protection Force continues to closely monitor conditions in the town of Dlubac located in the providence of El Polksa. Rebel forces from the radical nationalist group Black Sabbath have been linked to several terrorist bombings and attacks on the nearby towns. The strategic importance of Dlubac, overlooking one of the major routes entering El Polksa, makes this town a prime target for rebel activities. The U.S. 1-11th Infantry Battalion attached to the U.N. Protection Force has been tasked with coordinating U.N. activities within the region.

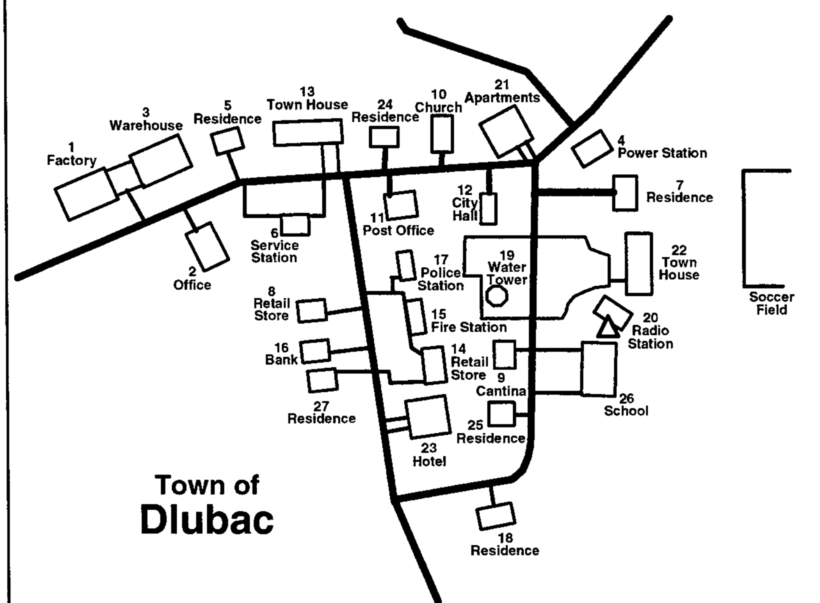


Figure 4. A general situation and numerous scenarios were developed for each CE as the basis of the structured scenario-based exercises. The general situation was presented as a "Press Release" to provide background. The scenarios were set in the fictional town of Dlubac, a virtual representation of the Shughart-Gordon urban training facility at Fort Polk, Louisiana.

A general situation and numerous scenarios were developed for each CE as the basis of the structured scenario-based exercise and, as should be expected, the situation and scenario for the FY 02 CE were rich with situational and tactical details. The general situation, in the form of a "Press Release", was provided to each new group of Soldiers (exercise participants) before they began their training. This helped to provide a background overview as to why they were executing the various scenarios. The general situation and a map of the fictional town (a virtual representation of the Shughart-Gordon MOUT facility at Fort Polk, Louisiana) are shown at Figure 4.

Each of the seven scenarios was designed to be 20-30 minutes in duration. They focused specifically on creating conditions that would encourage the Soldiers to use the various new devices and capabilities in the VE, and were designed to actively involve as many players as possible. The scenarios covered a variety of wartime and Support and Sustainment Operations (SASO), including:

- Roving Patrol (a familiarization exercise)
- Hostage Rescue (two scenarios)
- Deliberate Attack (two scenarios)
- Air Assault and Clear a Building

- Assault and Clear a Building
- Crowd Control
- Downed Helicopter

The two different versions of the Hostage Rescue and Deliberate Attack were designed to be comparable in terms of mission type and difficulty, although the starting points and objectives were different. By using these parallel versions, researchers were able to identify improvements in performance or effects of simulation fatigue across time.

Throughout each CE, information was collected from a variety of sources. Computers recorded the activities of both live and virtual Soldiers, participants filled out several questionnaires, structured interviews were conducted with leaders and their team members, and observers recorded key information about how the exercises progressed. For the final CE, the data collection instruments included:

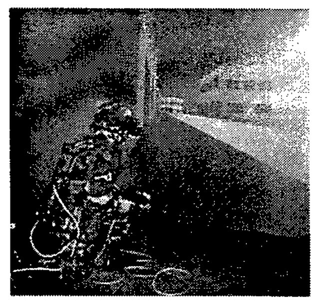
- *Demographic Questionnaire:* 18 questions about the Soldier's military career, training, personal characteristics, and experience with simulators.
- *SAF Performance Questionnaire:* 17 items on which Soldiers compared the performance of SAF with that of real Soldiers.
- *Simulator Capability Questionnaire:* 54 items asked Soldiers to rate their ability to perform various tasks in the simulators; 7 items concerning dynamic terrain features; 6 items on the simulator enhancements; and 8 items about the utility of AAR system in providing effective feedback.
- *Training Effectiveness Questionnaire*: 11 items asking Soldiers how much improvement in task performance resulted from the day's exercises.
- *Unit Evaluation Checklist:* used by observers to rate the frequency of 14 unit behaviors.
- *Voice Recognition Questionnaire*: 9 items for Soldiers on the effectiveness of the voice recognition system.
- The *Symptom Checklist*: a list of 16 symptoms, rated by the Soldiers in order to assess occurrences and severity of simulator sickness. Because use of VE can result in the experience of symptoms such as nausea and disorientation that could interfere with effective training, researchers conducted frequent checks on simulator sickness. The instances of discomfort were very low, never requiring adjustments to the training plan.

Advances in Technologies Throughout the STO

The first two years of the STO were spent in technology development and experimentation, laying the foundation for more rigorous test and evaluation in the last two years. Interoperability among the different technologies was always a major emphasis, as a failure of interoperability would be an immediate show-stopper for training, and training value was a major objective for the STO.

Now, as the results of the STO are analyzed and synthesized, it is possible to see in perspective the advances that were realized as a result of the collaborative efforts. Some of the specific technology advances, introduced over the four years of the STO, included:

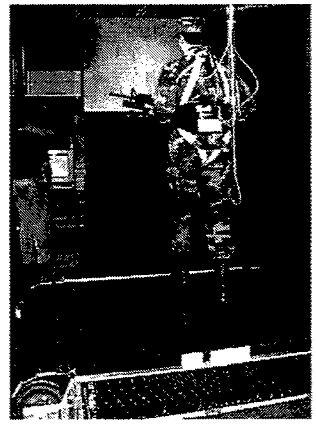
- *Realistic three-dimensional simulation environment.* The immersive 3D virtual simulator included the integration of dynamic terrain and the simulation of night conditions without the use of night vision devices. During the first year of the STO (FY 1999), but independent of it, the Squad Synthetic Environment (SSE) was acquired by the Soldier Battle Lab. The SSE systems provided the baseline for the primary type of individual Soldier simulators, which were enhanced continually over the next four years. The SSE included multiple immersive simulators (the cubicles described earlier, referred to as the Soldier Visualization Station,[3] or SVS) and compatible desktop systems. The SVS enabled the realistic and effective integration of an individual participant into a networked simulation.



The realistic Soldier Visualization Station (SVS) allows the Soldier to enter the simulated world and provides a realistic interface with both visual representation and real-time reactive performance effects.

- *Enhanced features for the Soldier Visualization Station (SVS).* The SVS did more than allow the Soldier to enter the simulated world. It also provided a minutely realistic interface for the Soldier, including both visual representation and real-time reactive performance effects. Some of the specific features included: virtual radio sets for communication; representation of electrical transformers, streetlights, and interior building lights that can be shot out and extinguished; the use of night tools such as flashlights and visible aiming lights; incorporation of a binocular capability; enhanced aiming complete with tracer rounds; airborne and thrown flares; fragmentation and concussion grenades; wounding of both SAF and virtual Soldiers and other entities; and ability to place and detonate satchel charges.

[3] The Infantry Center and School uses the term Squad Synthetic Environment (SSE) to describe the integrated set of individual simulators which are individually referred to by the developer (Advanced Interactive Systems, Inc.) and developing agency (STRICOM) as the Soldier Visualization Station (SVS). This report will use SVS to refer to an individual simulator, and SSE to refer to the integrated set of SVSs.

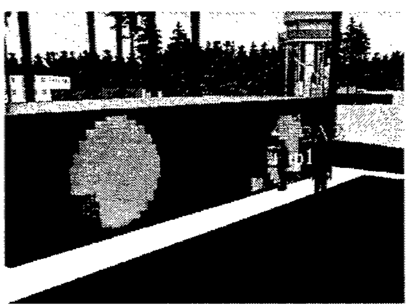


The Omni-Directional Treadmill used two interlocking belts moving at right angles, along with position and orientation sensors, to maintain the Soldier centered on the device while he walks or runs in any direction. The ODT was unique among the mobility interfaces used in the STO in requiring a fairly realistic expenditure of energy for locomotion.

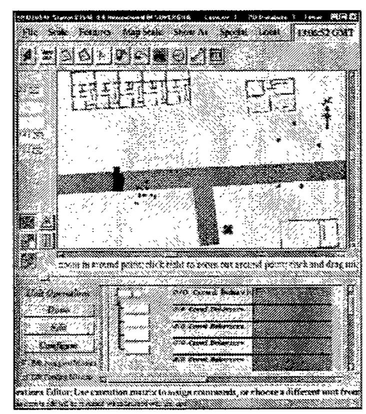
- *A mobility interface, the Omni-Directional Treadmill* (ODT). The ODT used two interlocking belts moving at right angles, along with position and orientation sensors, to maintain the Soldier centered on the device while he walks or runs in any direction. The ODT is unique among the mobility interfaces used in the STO in requiring a fairly realistic expenditure of energy for locomotion. In the third CE, some of the Soldiers used the ODT, while others used the SVS. Substantial changes were made to improve the control system and reduce the ambient noise level during the STO.

- *RealGuy, an alternate Soldier interface.* The RealGuy interface used video cameras and reflective markers to determine Soldier and weapon position and orientation. Use of RealGuy permitted realistic throwing of simulated grenades and recognition of hand and arm signals.

- *Dynamic Terrain Server (DTServer).* This technology provided the means to simulate the effects of blowing holes in buildings, such that the holes are sized appropriately for the munitions and building material and result in appropriate amounts of rubble. The DTServer, operating on a separate PC on the network, calculated damage effects and transmitted the results to the SVSs, the DISAF station, and AAR system. The use of a server allowed the addition and modification of algorithms without changes to other simulators on the network, reducing the costs of implementing dynamic terrain.



The Dynamic Terrain Server (DTServer) provides the means to simulate the effects of blowing holes in buildings such that holes are sized appropriately for the munitions and Soldiers can move through the breach.



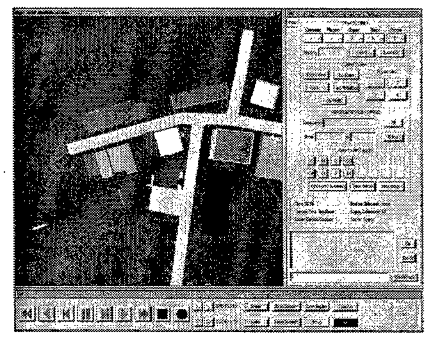
Using the Dismounted Infantry Semi-Automated Forces (DISAF) control system, the operator can insert crowds, snipers, hostages, and armed civilians. The system also models smoke/stun grenades and C4 explosives. Simulated Soldiers will move in appropriate formations and, when wounded, show realistic effects.

- *DISAF.* Developed as an enhancement to the capabilities of the OneSAF TestBed, DISAF added Infantry behaviors at the individual through squad levels and civilian behaviors to the virtual battlefield in a realistic fashion. Developments made under the STO focused on improving and adding new DISAF behaviors while reducing the responsibilities

and workload of the DISAF Operator. DISAF improvements included modeling smoke/stun grenades, C4 explosives, higher-fidelity wounding, various crowd units and corresponding behaviors, hostage and armed civilian behaviors, a sniper shooting behavior, formation keeping, and the addition of a joystick control mode.

- *Voice recognition and synthesis capabilities.* Voice synthesis was developed to address the need for team leaders to control their SAF subordinates. It permitted the SAF Soldiers to acknowledge a command, indicate failure to understand a command, indicate completion of a task, or report that they had come under fire. Improvements made to DISAF reduced operator workload, added new automated SAF behaviors to the repertoire, improved recognition accuracy and natural language compatibility, and incorporated SAF spontaneous speech.

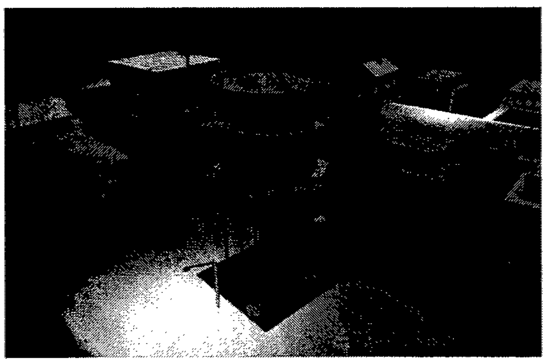
- *Dismounted Infantry Virtual After Action Review System (DIVAARS).* The AAR system was designed specifically for use with Infantry in urban terrain. The key capabilities of DIVAARS were digital videodisc (DVD)-like replay with synchronized audio and video. It included the use of a top-down view, digital data recording to permit immediate jumps to any point in the exercise, and the synchronized recording in digital form of the auditory communications. It also allowed the operator to mark or flag events and viewpoints, fly freely through the environment, teleport to pre-selected viewpoints, zoom in and out, capture "snapshots" for later viewing, toggle on and off information such as movement traces and individual identifiers, and select individual floors of multi-story buildings for viewing. During the AAR, the operator could also change viewing speed and location, and jump forward or backward to flagged events or times. A variety of exercise data presentations could be shown in either tabular or graphic form, such as Killer/Victim tables. The last round of enhancements included a "Windows-like" interface, addition of the capability to view building interiors, correction of problems with voice communication capture and replay, and new visual effects.



The Dismounted Infantry Virtual After Action Review System (DIVAARS) has a digital videodisc (DVD)-like replay with synchronized audio and video. Simplified controls allow the operator to track the exercise and capture or flag events for later review.

Each of these systems was developed independently, to some degree, but it was absolutely essential that the interoperability be achieved, so that they would serve as coordinated components of a larger, integrated system. Successful integration was best illustrated by dynamic terrain and smoke grenades. Both SAF and Soldiers in the SVSs could see, shoot through, and move through the holes created by the DTServer, and the AAR system displayed them as well. Smoke grenades produced smoke clouds of the same size shape, and color for the SVSs, DISAF, and DIVAARS.

Perhaps the most significant accomplishments of the VE STO are reflected in the level of sophistication and complexity of the scenarios that were run, as enabled by the advances in the technology. In the 1999 CE, at the end of the first year of the STO, five different scenarios were used. All five were variants of one basic scenario: move to an objective building, react to enemy contact en route, and finally assault the building. It was always daylight. Only one of the buildings could be entered by the SAF Soldiers. Few civilians were present, and their behaviors were limited to either standing still or moving on a preplanned route. Buildings could not be breached, and neither friendly nor enemy (SAF) forces could use smoke or grenades. A hit always equaled a kill. A fire team leader could control the SAF only by giving a verbal command to the DISAF operator, who then implemented that command at his console, and routes for the SAF had to largely be scripted in advance. AARs were limited to linear playback on a stealth viewer.



The enhanced graphics and Soldier visualization system in the final culminating event meant that scenarios could be conducted under conditions of either daylight or darkness, and Soldiers were able to shoot out lights to reduce their impact on the mission.

In the 2002 CE, however, there were six very different scenarios. Scenarios could be conducted at any time of day or night. The SAF could go anywhere, and could carry out some highly sophisticated behaviors, such as room clearing, autonomously. Civilians moved about freely, as individuals and in crowds, and could be armed. Holes could be blown at any location in any building. Flares, smoke, and grenades were available to all participants. Soldiers could be wounded as well as killed when hit. These factors greatly increased the variety and realism of the training situations that could be presented.

Perceptions from Soldiers: How the Technology Affects Performance

Throughout the four years of the STO, there were numerous enhancements and innovative approaches to improving the VE Soldier training. The ultimate tests of the STO's success was seen in the reactions and perceptions of the Soldiers and in the measured improvements in their task proficiency. In the paragraphs below, each of the specific technology areas will be discussed in terms of how they were addressed and what degree of success was achieved during the CEs (especially the last two). Discussion of the training value, the ultimate criterion, will be reserved to last.

Soldier Visualization Stations

At the individual Soldier level, the primary issue investigated was the suitability of the SSE to support Soldier task performance. That is, were Soldiers able to perform the tasks and activities they needed to be able to perform in order to carry out the training scenarios? In order to assess this, Soldiers participating in each CE were asked to rate their capability to perform 47 tasks and functions (e.g., execute planned route, communicate spot reports to squad leader, aim weapon).

The percentage of tasks rated positively (Good or Very Good) increased from 38% in 1999 and 30% in 2000 to 72% in 2002. The more highly rated tasks consisted of identification of types of people (such as enemy, civilians and non-combatants) and tactically significant areas, imprecise movement (e.g., move through open areas, take hasty defensive positions, maintain position relative to other team members), and communication. The lower rated tasks consisted of precise actions (fire weapon accurately), rapid movement (e.g., move close to walls, maneuver past other personnel within a room), distance estimation, and locating the source of enemy fire using either visual or auditory cues.

Soldiers reacted positively to such features as smoke, muzzle flashes from weapons, shadows for simulated human characters, placement for C4 charges by immersed Soldiers, and binoculars. They noted that time was accurately portrayed by the amount of light in the simulator, street lights were realistic, and that shooting out street lights to reduce their impact on the mission was realistic. They were less strong in their belief that night conditions were accurately portrayed in the simulator and that building interior lights were realistic, but stated that shooting out interior building lights to reduce their impact on the mission was realistic. While they liked this idea of having grenades and other weaponry besides the rifle, there was some dissatisfaction with the lack of realism in how they employed these weapons.

While it was satisfying to find that Soldier ratings of the simulator capabilities were generally higher in the last year of the STO than in previous years, it was difficult to relate the changes in ratings on specific items to a likely cause. The most likely reason for the improvement is that the Soldiers responded to the individual items on the basis of both the specific cue intended and the overall quality of their experience in the simulators. The last capabilities to be introduced, like smoke and grenades, were rated highly (and the absence of which was a cause for complaint in prior years); this may have increased the overall quality of this experience and, by extension, the ratings of individual tasks that were not directly affected.

Some Soldier interface needs were not totally solved. The most prominent ones are the need for better sound localization, more accurate weapons (particularly when in the prone position), and improved arrangement of cables within the simulator.

Soldier Locomotion (Movement) Devices

During the third CE, the ODT, though still somewhat less mature as a technology than the SVS, was included and examined in terms of both overall performance and user interaction and reaction. It received mid-to-high ratings for its ability to allow Soldiers to move across open terrain and to move naturally, maintain balance, and maneuver close to other people in the VE, but lower ratings on other movement tasks. In general, the Soldiers felt that their movement through the VE using the ODT was too slow. Because the ODT sometimes caused the Soldiers to move when they were not ready (and because of simple individual differences in comfort levels), some Soldiers indicated that they did not feel entirely safe while operating on the ODT.

The use of a head-mounted display, combined with the ability to turn their bodies on the ODT, allowed them to observe 360° around themselves. They recommended, though, that the "working area" of the ODT be larger, and that the various mechanical linkages and cables be run differently so that they do not interfere with the user's movements. These modifications would allow ODT users to take longer – more natural – strides, crouch, kneel, go prone, and crawl. ARL HRED is developing a next-generation ODT based on this feedback.

Dynamic Terrain

The dynamic terrain feature was first examined as an integral part of VE during the third CE, in FY 2001. Real-time alteration of the various databases required during the simulation was a very complicated process which sometimes resulted in unexpected and unrealistic changes. To work around the limitations of the feature, initial orders presented to the squad explicitly called for a specifically-located breach to be created during the mission. Overall, the battlefield environment, the process of creating a hole, and the hole itself were perceived as being realistic, although the rubble was perceived as being less realistic and having little effect.

The final CE in FY 2002 employed a much less restricted approach to the use of the breaching capability. The squad leader could decide during a mission when and where to use breaching. As a result, the breaching capability was used much more frequently than the preceding year. However, the percentage of successful (usable) breaches was much lower. On several occasions the size, shape and/or location of the breach was not what the squad expected or wanted. The dynamic terrain feature was also integrated with DISAF capabilities, and this implementation was well-received. The system successfully processed C4 explosive detonations issued from both the SVS and SAF entities. Shots fired from DISAF or the SVS that hit buildings left appropriate "bullet holes."

Semi-Automated Forces Representing Individual Soldiers (DISAF)

New behaviors were added to the DISAF repertoire each year, and were evaluated during each of the CEs for appropriateness, realism, and impact on DISAF operator workload. By the time of the final CE, there was improvement in most of the ratings of DISAF performance, relative to 1999 and 2001. Soldiers indicated that SAF troops can locate/identify the enemy better than real Soldiers, but have trouble moving to and firing at the correct locations and reporting their observations or activities to their team fire leader. The addition of civilian crowds, armed civilians, and corresponding behaviors provided a more realistic crowd control training exercise. Smoke grenades were effectively used by the trainees to mask their movements from SAF enemies, and flash-bang (a.k.a., "stun") grenades effectively suppressed those enemy Soldiers during room clearing operations. Wounding effects to SAF entities were consistent with the location and severity of their wound.

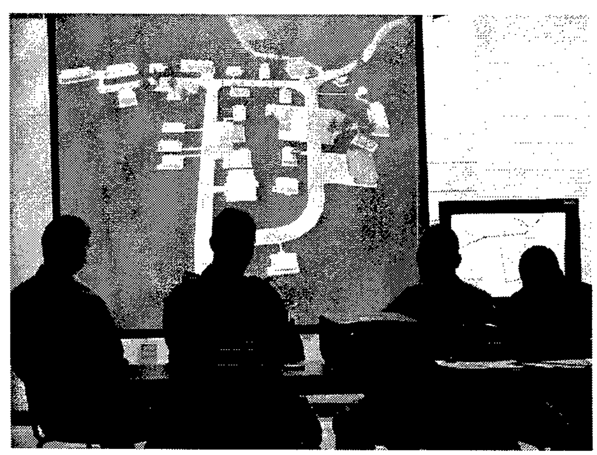
Voice Control of the SAF

In its first outing, during the third CE, the voice recognition feature did not work satisfactorily at all, in terms of how well the fire team leader could control SAF Soldiers, but most of the problems were associated with the selected speech recognition software itself, rather than its incorporation into DISAF.

Speech recognition accuracy was substantially better in the following year. Overall recognition rate was 70%, however, which indicated a need for further improvement. The system demonstrated that a team composed of SAF entities and commanded by a human can participate meaningfully in an exercised containing live and synthetic teams. The extended use of natural language phrasing and naming conventions seemed to allow new users to become familiar with and use the system without focusing on the speech syntax.

DIVAARS Features and Capabilities

The AAR system was a major component of the third and final CE efforts. In FY 2002, at the final CE, Soldiers' ratings were overall very high. Nearly all of the Soldiers felt the AAR system made clear what happened during a mission, why things happened the way they did, and how they could do better in accomplishing the mission. The lowest rated item in 2001, effectiveness in replaying communications, showed substantial improvement in 2002. This is consistent with the observed improvement in intelligibility of the communications.



Nearly all of the Soldiers felt that the Dismounted Infantry Virtual After Action Review System (DIVAARS) made clear what happened during a mission, why things happened the way they did, and how they could do better in accomplishing the mission.

Overall, the AAR system was judged to be a highly reliable tool to assist in data collection, key event monitoring, AAR planning, and AAR presentation. Most features worked very well. Preset views of probable critical points or potential vulnerabilities during the mission provided valuable locations to begin observations from as the mission progressed. The captured video, top-down floor views, ability to remove portions of buildings, entity views, and tabular data provided leaders and Soldiers with high fidelity observations and data to document their own actions and reactions, as well as actual OPFOR or potential OPFOR perspectives. The jump forward/back, variable speeds, and real-time playback let the leaders and Soldiers understand the results of their movements, actions, and inactions. Sound playback further reinforced this understanding. With mission duration varying from seven to thirty minutes, the flexible nature of the system provided the capability to assemble the resources for a solid AAR in five to ten minutes.

Training Effectiveness: Impact on Soldier Proficiency

From the beginning of the STO, training effectiveness has been the primary goal. Any number of training objectives could conceivably be subsumed within the original intent: to develop "a training system for dismounted Soldiers that is realistic *and effective*" [emphasis added].

Even at the outset, the SSE was expected to be more appropriate for the squad leader and fire team leaders than the squad members. This was considered to be both cost effective and consistent with the strengths and weaknesses of the technology. A leader trainer would require fewer costly simulators than a Soldier trainer. Training for fire team members would necessarily entail assessment of weapon use, but the earlier experiments had shown weapons tracking to be relatively inaccurate. As a result, the training effectiveness assessment focused on the squad and fire team leaders, who perform many tasks that do not require weapons use, and secondarily on the squad as a whole.

Leader ratings of training effectiveness constitute perhaps the biggest success story of the STO. Generally, squad and fire team leaders said that their performance improved as a result of the training. Since 1999, there has been a consistent increase in leader ratings of training effectiveness across 10 of the 11 tasks that they were asked to rate. The percentage who said that their performance improved at least slightly ranged from 82% for the task "Clear a building" to 100% for "Assess the tactical situation," "Control your squad or fire team," and "Plan a tactical operation." In general, ratings for coordination, communication, and control tasks were higher than those for specific unit tasks or battle drills, although this difference was not as pronounced in FY 2002 as it had been in previous years.

In the final CE, the results were examined for evidence of performance improvement with practice. The overall trend was positive, although there was a sharp decline in performance on the final scenario of the second day. This occurred for every squad.

Since each squad had different scenarios in both the seventh and eighth positions in their sequence, it is unlikely to result from a more difficult final scenario. Fatigue or a "going home" letdown are the most likely causes.

Two of the scenarios underlying the exercises were deliberately constructed to be executed in separated, parallel versions, so that performance ratings between two iterations could be compared. Overall, of the six possible comparisons (three squads times two pairs of scenarios), five showed superior performance on the on the second occurrence, as shown in Figure 5.

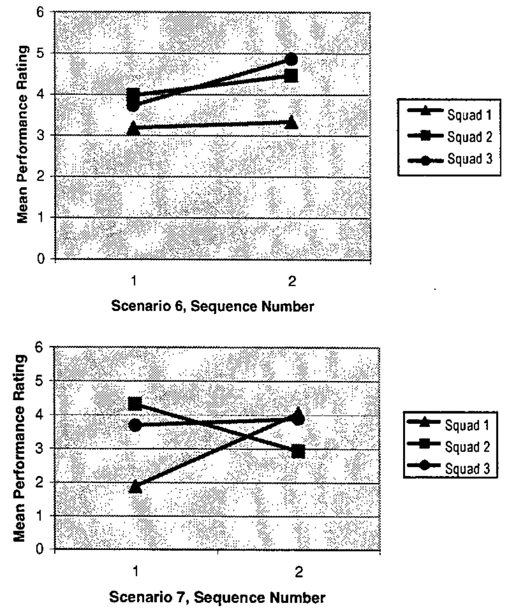


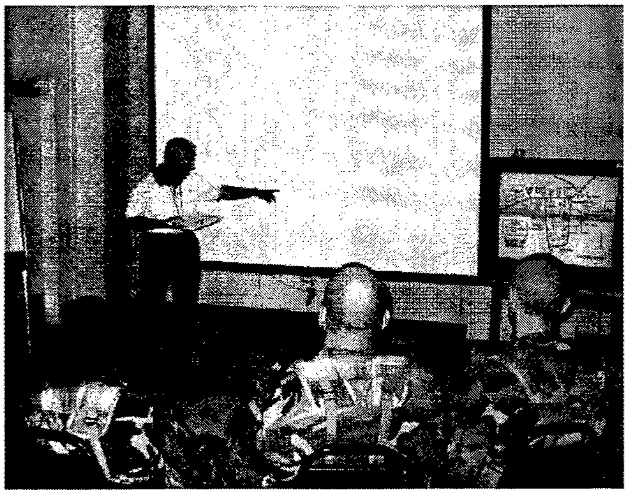
Figure 5. For the two exercise scenarios that were performed in parallel versions by three squads, five of the six possible comparisons showed superior performance on the second occurrence.

The Road Ahead: Lessons Learned and Recommendations

In general, the individual systems performed well during the CE. Although problems were encountered at the individual system level, it was possible to correct the major ones on the spot. The technologies and their interoperability, however, were not the only key features of the STO experience. The lessons learned and recommendations for future development are equally important. This section discusses some of the general lessons learned about the conduct of the CE and qualitative observations about system, participant, and trainee Soldier performance.

Integration and interoperability of the diverse technologies was a central goal for the STO. Problems stemming from the integration of the systems were usually more difficult to diagnose and correct during the CEs than problems with individual systems. It is obvious in retrospect that it is nearly impossible to overestimate requirements for system set-up, integration, and testing prior to a major event such as the CEs. If a development and testing schedule does not allow significant time for integration and testing, to include testing of all scenarios on all systems with a realistic participant load, then a key link in the chain is weakened, and the desired outcome will have a low probability of success.

Types of systems integration challenges encountered included heavy network traffic, visual and physical model inconsistencies, and use of system-specific data packets which could not be interpreted by other systems. Network traffic became a problem because while the bandwidth of the LWTB network was limited, no managerial or technical effort was made to control requirements for bandwidth or to allocate it among the various systems. Requirements for bandwidth across systems must be a consideration in the future, with potential solutions including ways to both increase bandwidth and decrease requirements.



Much of the training success was attributed by Soldiers to the contributions of a skilled after action review (AAR) Leader in identifying and interpreting key events and conducting the AAR.

Exercises without feedback cannot be considered to be effective for training, and the feedback capabilities provided by DIVAARS were well-received in the CEs. There are a number of new features that could be added to DIVAARS to improve training effectiveness. The most important would be the incorporation of a commercial graphics package to generate instructional support materials for the AAR process. Word charts or graphic illustrations could be used to support training objectives in whatever format unit leaders/trainers would choose to adapt to the AAR and training process. Second would be the capability to produce multi-media take home packages, so that Soldiers and units could review their exercises after their training experience has been completed. The third would be the capability to incorporate scenario control information, such as phase lines and boundaries, into the AAR. The last would be the capability to automatically detect and mark certain critical events, such as fratricide, without intervention by the AAR Leader.

Events also showed that much of the success, from the Soldier's perspective, could be attributed to use of a skilled AAR Leader to identify and interpret key events and conduct the AAR and a dedicated, trained operator. Separating the duties of the system operator and the AAR Leader vastly improved the performance of both tasks. The operator was able to concentrate more on the scenarios and mentally forecast events as they were scheduled to occur. This ensured that items such as environmental conditions and timed events were properly implemented to support each scenario. Having a separate person conduct the AAR removed this requirement from the operator's additional duty list and gave it the emphasis it required.

Some aspects of the DIVAARS interface, such as changing preprogrammed views, are simple to operate now, while others, such as free flying with the mouse, demand extensive skill and practice. Conversion of some capabilities to a joystick type control, and creation of a GUI that would permit rapid access of flagged events at optimized views, could greatly increase the effectiveness of the interface while not complicating the job of the operator.

The focus of the research, however, is ultimately centered on training effectiveness. Judging from the findings of the STO CEs and the other related investigations, there is a broad range of tactical skills that could conceivably be trained in VE. At one end of the continuum are small unit leader decision-making skills. Pleban, Eakin, Salter, and Matthews (2001) found that these skills could be trained effectively in VE. Training these skills does not require a high fidelity, fast, or precise interface with the

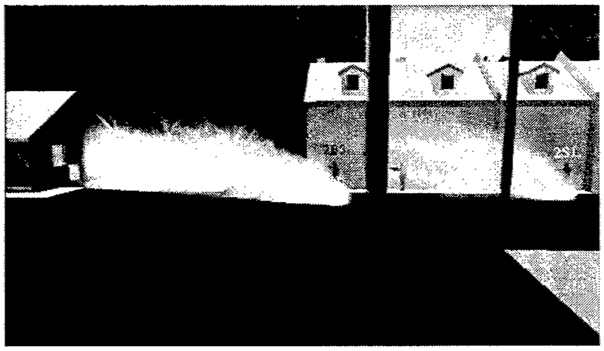
Research findings suggest that the virtual environment will be effective in training small unit leader decision-making and command and control skills.

virtual world. Success is more likely to depend on the scenarios and the quality of the role players.

At the other end of the training complexity continuum are the specific squad drills and tasks, like building clearing, which involve less decision-making and more communication and coordination among unit members, but above all require rapid and precise positioning, movement and use of weapons. A recent experiment by Pleban and Salvetti (2003) indicates that, while there are a number of interface and technology problems to be overcome, VE nevertheless shows promise for this type of training as well, although it appears not to be effective as real world training at present. The types of squad-level exercises conducted during the last two CEs fall somewhere in the middle, targeted at improving leader decision-making and command and control skills in a variety of mission types while also allowing squad members to practice urban operations tasks.

Given the current state of technology, we would not propose VE as a total replacement for real world tactical training for Infantry Soldiers. This should come as no surprise: Similar conclusions emerge in research on VE for other types of military training as well. However, VE could be used effectively for some types of training and some stages of training. It could provide the "walk" phase of the training, concentrating on improving the decision-making, situation awareness, communication, and coordination skills. Real world training would then build on acquired skills, placing greater emphasis on the motor skills. VE training also has the advantage of being both more readily standardized and more flexible than a real world urban training center, in that terrain databases and environmental conditions can be structured yet changed rapidly. And considerations of safety, environmental protection, and budgets also recommend VE training as part of the overall training strategy for the Infantry.

The substantial improvements that have been made over the last four years in the capability of virtual simulation to provide training for the leaders of small Infantry units raises hopes for future developments. The advances in technology have greatly increased the level of realism that is possible through virtual simulation and the breadth of tasks that can be trained. While the samples are small, both leader self-ratings and independently-obtained performance scores indicate that Soldier skills improved with practice in VE. The FY 01 and FY 02 CEs focused on sustainment and support operations, and in that context, the leaders reported more improvement in command and control, coordination and communication, planning, and situational awareness skills than in skills conducting specific unit tasks or battle drills. Similarly, Pleban, Eakin, Salter and Matthews (2001) found VE effective for training platoon leader decision-making skills. More recent research by Pleban and Salvetti (2003) found that training squad level building clearing in VE can transfer to the real world.



Realistic use of smoke grenades enables Soldiers to practice techniques for crossing open spaces and assaulting buildings during mission rehearsal.

Beyond its utility in training, VE also offers advantages for mission rehearsal and concept exploration. When Infantry units are preparing to address real-world missions, a mature VE can give them the opportunity to rehearse their command and control in a realistic replica of their target environment, learn some of the key characteristics of the locale, and establish the foundational plans that will later be adapted as conditions change. Such use will require highly portable and flexible systems, and already industry is addressing these needs. As the U.S. military looks to the future, the accelerating transformation to joint operations will increasingly require that distributed units and commands quickly coalesce into coherent battle forces, and the VE training and rehearsal capabilities must be designed and developed to support the requirement.

As it moves from the current capabilities into the future, the U.S. Army is examining new doctrine, equipment, and organizations. The VE can serve as a testbed for exploring concepts and further developing equipment and capabilities for Soldiers. By trying out these plans and ideas in VE, modifications can be introduced in a deliberate way with meticulous control of extraneous variables, thus helping to increase the scientific rigor of the testing and evaluation programs.

While there are still further improvements that can be made in the individual technologies, as identified earlier in this report, the next step should be the production of a prototype system, taking a total system approach to development.

Science and Technology Objective: Virtual Environments For Dismounted Soldier Simulation, Training and Mission Rehearsal

ARMY NEED: Both today and in the future, the Army needs vastly improved dismounted Soldier simulation capabilities. The Army needs simulations that allow Soldiers and units to train effectively even if they do not have the opportunity to participate in large numbers of high fidelity field training exercises. Soldiers and units also need effective rehearsal tools that prepare them for specific combat operations in all types of terrain.

Further, the Training and Doctrine Command needs inexpensive and high fidelity prototyping and testing systems that will allow them to explore and evaluate potential doctrine, organizations, equipment, and Soldier characteristics. These needs are very important today; they are likely to be critically important during the Army After Next time frame.

DESCRIPTION: The effort will focus on overcoming the following critical technological challenges that currently prevent high fidelity dismounted Soldier simulation: limited field of view and resolution of visual display systems; simulating locomotion: tracking weapons and body positions; creating realistic performance of computer-controlled dismounted friendly and enemy Soldiers; simulation of night equipment and sensor images; making terrain and structures dynamic; developing appropriate training strategies and methods; assessing individual and unit performance; developing training materials quickly and easily; and determining transfer of training from virtual to live environments.

TECHNICAL CONCEPT: Emerging Virtual environment (VE) technologies, such as low cost computer image generators, immersive helmet mounted displays, locomotion platforms, and intelligent computer-controlled forces have the potential to provide training, mission rehearsal, and experimentation capability for dismounted Soldiers and leaders. However, VE potential is currently unrealized because the Army has not yet solved critical hardware and software limitations, documented effective methods and strategies, or created training the support packages necessary to use it. The effort will build on the previous efforts of the participating organizations in the development and use of virtual simulations.

(Extracted from STO Nomination)

PRODUCT: The product of this effort will be a High Level Architecture (HLA)-compliant integrated prototype system based on validated requirements for dismounted Soldier simulation. It will include the following components and capabilities:

- Locomotion platform which provides realistic perception of movement and accurate energy expenditure.
- Visual system which can simulate a variety of night vision sensors and equipment accurately.
- "Intelligent" computer-controlled forces to represent enemy, friendly and neutral forces. They will produce tactically sound behavior reflecting training and environmental and psychological stressors, and respond to voice and gesture commands.
- Dynamic Terrain, including damage to structures, rubble and other micro-terrain obstacles; and physically based smoke/obscurants.
- Features to enhance the effectiveness of training and mission rehearsal.
- Simulated command and control tools (planning, coordination, and monitoring)
- Demonstrated effectiveness of the system.

BENEFITS TO THE ARMY:

- Improved training and development for dismounted small unit leaders.
- Effective means for joint training and rehearsal of dismounted and mounted forces.
- Capability for dismounted Soldiers to rehearse a mission in a simulation of the area in which it will be conducted.
- Capability to use virtual simulations to evaluate concepts and equipment for dismounted forces.

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Acronyms

AAR	after action review
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ARI-IFRU	U.S. Army Research Institute-Infantry Forces Research Unit
ARI-SSRU	U.S. Army Research Institute-Simulator Systems Research Unit
ARL-CISD	U.S. Army Research Laboratory Computational and Information Sciences Directorate
ARL-HRED	U.S. Army Research Laboratory Human Research and Engineering Directorate
CCTT	Close Combat Tactical Trainer
CE	culminating event
C4	command, control, communications, and computers
DA	Department of the Army
DIS	distributed interactive simulation
DISAF	dismounted infantry semi-automated forces
DIVAARS	dismounted infantry virtual after action review system
DTServer	dynamic terrain server
DVD	digital videodisc
DWN	Dismounted Warrior Network
FY	fiscal year
LWTB	Land Warrior Testbed
MOUT	military operations in urban terrain
ODT	Omni-Directional Treadmill
OPFOR	opposing forces
PC	personal computer
PEO-STRI	Program Executive Office – Simulation, Training, and Instrumentation
R&D	research and development
SAF	semi-automated forces
SASO	support and sustainment operations
SOP	standing operating procedure
SSE	Soldier simulation environment
STO	Science and Technology Objective
STRICOM	U.S. Army Simulation, Training, and Instrumentation Command
SVS	Soldier Visualization Station
TRADOC	U.S. Army Training and Doctrine Command
VE	virtual environment

REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy)	2. REPORT TYPE	3. DATES COVERED (from. . . to)
May 2004	Final	October 1999 – September 2003

4. TITLE AND SUBTITLE Virtual Environments for Infantry Soldiers *Report on the Science and Technology Objective: Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal*	5a. CONTRACT OR GRANT NUMBER DASW01-99-D-0012 5b. PROGRAM ELEMENT NUMBER 2Q622785A
6. AUTHOR(S) Charlotte H. Campbell, Human Resources Research Organization Bruce W. Knerr and Donald R. Lampton, U.S. Army Research Institute for the Behavioral and Social Sciences	5c. PROJECT NUMBER A790 5d. TASK NUMBER 202a 5e. WORK UNIT NUMBER C02
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Human Resources Research Organization 66 Canal Center Plaza, Suite 400 Alexandria, VA 22333-5600	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: DAPE-ARI-IF 12350 Research Parkway Orlando, FL 32826-3276	10. MONITOR ACRONYM ARI 11. MONITOR REPORT NUMBER Special Report 59

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Technical Monitors: Dr. Stephen L. Goldberg and Dr. Bruce W. Knerr

14. ABSTRACT *(Maximum 200 words)*: This report describes the work on a Science and Technology Objective (STO) entitled Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal. The four-year (Fiscal Year [FY] 99-FY 02) STO effort was proposed to address a range of U.S. Army future operational capabilities described in U.S. Army Training and Doctrine Command (TRADOC) Pamphlet 525-66 (U.S. Army Training and Doctrine Command, 1997). The STO activities and goals were focused on overcoming critical technological challenges that prevented effective Infantry Soldier simulation. The U. S. Army Research Institute for the Behavioral and Social Sciences (ARI) led a team of both government and industry developers in examining simulation capabilities for Infantry. The other government partners were the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM) and the U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) and Computational and Information Sciences Directorate (ARL-CISD). Each of the major players had a particular area of interest, but all worked together to explore concepts and systems and to recommend directions for further work on training, concept development, and mission rehearsal. The overall goal for the STO was to develop a demonstration Infantry leader trainer at the fire team, squad, and platoon level. The envisioned system would include a variety of capabilities: for leader trainees to execute a series of realistic training scenarios (combat operations and support operations) in the simulator; for subordinates, other friendly forces, enemy forces, and civilians to be represented by computer-controlled or semi-automated agents; and for repeated practice, enhanced by training features, coaching, and AARs, that would build decision-making and coordination skills.

15. SUBJECT TERMS Virtual Environments, Infantry, Simulator Sickness, Locomotion Simulators, DISAF, Semi-Automated Forces, After Action Review, Voice Recognition, Voice Synthesis, Training Effectiveness

SECURITY CLASSIFICATION OF			19. LIMITATION OF	20. NUMBER	21. RESPONSIBLE PERSON
16. REPORT	17. ABSTRACT	18. THIS PAGE	ABSTRACT	OF PAGES	(Name and Telephone Number)
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